

AD-A244 096



TION PAGE

Form Approved
OMB No. 0704-0188

average 1 hour per response, including the time for reviewing instructions, searching existing data sources, the collection of information. Send comments regarding this burden estimate or any other aspect of this Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503

1. DATE OCTOBER 1991		3. REPORT TYPE AND DATES COVERED FINAL REPORT 15 Mar 88 - 30 Aug 91	
4. TITLE AND SUBTITLE ELEMENTARY EXCITATIONS, OPTICAL AND TRANSPORT PROPERTIES OF ARTIFICIALLY STRUCTURED MATERIALS		5. FUNDING NUMBERS DAAL03-88-K-0026 (2)	
6. AUTHOR(S) JOHN J. QUINN			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) BROWN UNIVERSITY PROVIDENCE, RI 02912		8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U. S. Army Research Office P. O. Box 12211 Research Triangle Park, NC 27709-2211		10. SPONSORING/MONITORING AGENCY REPORT NUMBER ARO 25167.16-PH	
11. SUPPLEMENTARY NOTES The view, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.			
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited.		12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) A NUMBER OF PROBLEMS INVOLVING THE ELECTRONIC PROPERTIES OF ARTIFICIALLY STRUCTURED SEMICONDUCTORS HAVE BEEN STUDIED. THE STUDY OF THE GROUND STATE AND THE ELEMENTARY EXCITATIONS OF A DOUBLE QUANTUM WELL SYSTEM HAS REVEALED THE EXISTENCE OF A NOVEL "EXCITONIC CHARGE DENSITY WAVE STATE." DONOR STATES, BOTH SINGLY AND DOUBLY OCCUPIED, IN A MODULATION DOPED QUANTUM WELL HAVE BEEN INVESTIGATED. MAGNETIC POLARON EFFECTS IN A VARIETY OF ARTIFICIAL STRUCTURES HAVE BEEN STUDIED.			
14. SUBJECT TERMS EXCITONIC CHARGE DENSITY WAVE, DONORS IN QUANTUM WELLS, MAGNETIC POLARON		15. NUMBER OF PAGES	
		16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL

DTIC
EXCITONIC
JAN 10 1992
S D

**ELEMENTARY EXCITATIONS, OPTICAL AND TRANSPORT
PROPERTIES OF ARTIFICIALLY STRUCTURED MATERIALS**

FINAL REPORT

JOHN J. QUINN



OCTOBER 1991

**U.S. ARMY RESEARCH OFFICE
DAAL03 - 88 - K - 0026**

BROWN UNIVERSITY

Accession For	
NTIS GDA31	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution	
Availability	
Dist	Availability for
A-1	Supplier

92 1 1 3

**APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED**

92-00553



A. PROBLEMS STUDIED

1. Phase Transitions in Double Quantum Well Systems.

The quasi two-dimensional gas of electrons (or holes) which can occur in certain narrow quantum well systems is known to undergo a transition to a Laughlin condensed state or to a charge density wave state (or Wigner crystal) at very low temperatures and high magnetic fields. We have studied the problem of a pair of two dimensional layers separated by a distance d of the order of the magnetic length $\ell = \sqrt{\hbar c / eB}$ in the presence of a strong magnetic field. Here interlayer Coulomb interactions are important and can affect the nature of the ground state.

2. Donor States in Quantum Well Systems.

The spin density functional technique has been used to investigate donor levels in a modulation doped quantum well. The binding energy of the D^0 (donor with a single bound electron) and D^- (donor with a pair of bound electrons) states is studied as a function of the electron concentration in the quantum well. The optical properties of a system containing N_1 donors and n_s electrons (where $N_1 < n_s$) is studied for N_1 sufficiently small that donor-donor interactions can be ignored.

3. **Magnetic Polaron Effects in Artificially Structured
Semimagnetic Semiconductors.**

The exchange interaction between a free carrier and a magnetic ion leads to a non-linear Schrodinger equation for the electronic wave function. This non-linearity can have dramatic effect on the electronic and transport properties of array of quantum wells, quantum wires and quantum dots. Several different structures have been investigated.

4. **Diagrammatic-Method for the Analyses of Finite
Multilayer Structures.**

We have developed a scheme for determining the response functions and normal modes of a finite array of layers in terms of simple diagrams and rules for associating with each diagram an analytic contribution to the dispersion relation of the excitation being studied. The method has been applied to plasmons, phonons, magnons and electronic states in a finite array of thin layers. We are currently investigating the problem of direct electromagnetic generation of sound in a finite array of space charge layers on a semiconducting substrate.

B. Summary of Most Important Results

1. For a neutral system consisting of an electron layer separated from a hole layer by a distance d , the ground state for small values of d is a condensed excitonic liquid. By studying the coupled equations of motion of the exciton density, electron density and hole density fluctuations in a generalized time dependent Hartree Fock approximation, we found an instability of the homogenous excitonic liquid for d larger than critical value d_c , where d_c depends on the Landau level filling factor ν . The nature of the ground state was explored by assuming that certain correlation functions are non-vanishing in the new state. The new state is called the "excitonic charge density wave state," and its properties and elementary excitations have been investigated.
2. The conditions under which the negatively charge donor state D^- exists in the presence of a free electron gas in a narrow quantum well have been studied. The binding energy and 1S_0 to 1P_1 transition energy have been determined for various sample parameters including the free electron concentration n_s .
- 3 and 4. The most important results on magnetic polarons and on the novel diagrammatic technique for multilayer systems have been reported in previous reports.

C. List of Publications and Technical Reports.

- "Many-Body Effects in a Layered Electron Gas," (with P. Hawrylak and G. Eliasson) Phys. Rev. B37, 10187, 1988.
- "Collective Electronic Excitations in Systems with Spatially Varying Electron Density," Proc. of Taxco Workshop on Electromagnetic Properties of Surface, 1988.
- "Plasmon Bands in Metallic Superlattices: Retardation Effects," (with G. Gonzalez de la Cruz and G. Eliasson), Proc. of Taxco Workshop on Electromagnetic Properties of Surfaces, 1988.
- "Collective Excitations in a Multiple Quantum Well System with Barrier of Finite Height," Physical Review B38, 5617, 1988, (with Zhu, Xia, and Hawrylak).
- "Surface Magnetoplasmon Polaritons in Truncated Superlattice Systems," Phys. Rev. B38, 4205, 1988, (with Wallis).
- "Bulk and Surface Plasma Waves in Semiconducting Superlattices," to appear in Spatial Dispersion in Solids and Plasmons, (with G. Eliasson and P. Hawrylak) ed. P. Halevi, Cambridge University Press, 1989.
- "Collective Excitations of an Electron-Hole Plasma in Semiconductor Superlattices with Zero Valence Band Offset," Solid State Comm., 69, 397, 1989, (with Eliasson, Hawrylak, Zhu and Xia).
- "Novel Collective Excitations Spectrum and Lifetime in a Tunneling Semiconductor Superlattice," Phys. Lett. A 135, 307, 1989, (with Zhu and Xia).
- "Quasiparticle Lifetime of Excited Carriers in a Semiconductor Superlattice," Phys. Rev., B39, 3305, 1989, (with Xia and Zhu).
- "Collective Excitations of Electron-Hole Plasma in Semiconductor Superlattice," to appear (1990). Trends in Plasma Physics (with Eliasson, Hawrylak, Zhu and Xia).
- "Excitonic Insulator Transition in a GaSb/Al Sb/InAs Quantum Well Structure," Solid State Commun., 75, 595, 1990, (with X. Zhu).

- "Self-Trapped Magnetic Polarons in Two-Dimensional Semimagnetic Semiconductors," Submitted to Solid State Commun., 1990, (with X. Zhu and P. Hawrylak).
- "A Novel Diagrammatic Method for the Analysis of Finite Multilayer Structures," Proc. of 20th Int. Conf. on Physics of Semiconductors, Thessaloniki, Greece, 1990, (with G. Vecris).
- "Novel Diagrammatic Method for Analyzing the Surface Electronic Modes of Finite Multilayer Structures," Proc. of the Int. Conf. on Solid Films and Surfaces, Providence, 1990, (with G. Vecris).
- "Novel Diagrammatic Method for the Analysis of Finite Periodic and Aperiodic Multilayer Structures," Solid State Comm. 76, 1071, 1990, (with G. Vecris).
- "Hydrogenic Impurities in Quantum Well Structures," submitted to Phys. Rev., 1991, (with X. Xia).
- "Exact Analytic Dispersion Relation for Dipolar Magnetostatic and Magnetoretaarded Modes in Finite Superlattices, Phys. Rev., 1991, (with G. Vecris).
- "Excitonic Charge Density Wave Instability of Spatially Separated Electron-Hole Layers in a Strong Magnetic Field," Phys. Rev. Letters 67, 895, 1991, (with Chen).
- "Hydrogenic Impurities in Quasi Two-Dimensional Electron Gas Systems," submitted to Phys. Rev., 1991, (with X. Xia and X. Zhu).
- "Tunneling in a Periodic Array of Semimagnetic Quantum Dots" to appear in Phys. Rev., 1991, (with Hawrylak and Grabowski).

D. List of All Participating Scientific Personnel Showing Any Advanced Degrees Earned by Them While Employed on the Project.

Dr. Ximing Chen
 Dr. Yun Zhu
 Dr. Xiaoguang Xia, Ph.D. Brown University, 1991
 Dr. Xiaodong Zhu

5. **Report of Inventions** -- None.
6. **Bibliography** -- All references are contained in the papers cited under publications.
7. **Appendix** -- Final Financial Report.

Standard Form 1035 (Duplicate)					PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL CONTINUATION SHEET		Voucher No 30-FINAL																																																			
							Schedule No																																																			
							Sheet No 2																																																			
U.S. DEPARTMENT, BUREAU OR ESTABLISHMENT Department of																																																										
Number and Date	Date of Delivery of Service	Articles or Services <small>Enter Description, Item No. of Contract or Federal Supply Schedule and other and other info. deemed necessary</small>	QUANTITY	UNIT PRICE Cost Per		AMOUNT																																																				
<div style="display: flex; justify-content: space-between;"> <div> BROWN UNIVERSITY Providence, Rhode Island 02912 </div> <div> Contract No. DAAL03-88-K-0026 </div> <div> Total Estimated Costs \$ 186,485.00 Overhead 0.16 </div> </div> <div style="text-align: center; margin-top: 20px;"> Analysis of Claimed Current and Cumulative Costs </div> <table style="width: 100%; margin-top: 10px;"> <thead> <tr> <th style="width: 55%;"></th> <th style="width: 20%; text-align: center;">Amount for Current Period Billed</th> <th style="width: 25%; text-align: center;">Cumulative Amt From Inception</th> </tr> </thead> <tbody> <tr> <td colspan="3"><u>Major Cost Elements:</u></td> </tr> <tr> <td>Line 1 Salaries & Wages</td> <td style="text-align: right;">\$ 0.00</td> <td style="text-align: right;">\$ 112,565.75</td> </tr> <tr> <td>Line 2 Fringe Benefits</td> <td style="text-align: right;">0.00</td> <td style="text-align: right;">27,671.42</td> </tr> <tr> <td>Line 3 Materials & Services</td> <td style="text-align: right;">0.00</td> <td style="text-align: right;">5,096.09</td> </tr> <tr> <td>Line 4 Travel</td> <td style="text-align: right;">0.00</td> <td style="text-align: right;">3,297.86</td> </tr> <tr> <td>Line 5 University Services</td> <td style="text-align: right; border-top: 1px solid black;">0.00</td> <td style="text-align: right; border-top: 1px solid black;">556.26</td> </tr> <tr> <td>Line 6 Sub Total</td> <td style="text-align: right;">\$ 0.00</td> <td style="text-align: right;">\$ 149,187.38</td> </tr> <tr> <td>Line 7 Equipment</td> <td style="text-align: right;">0.00</td> <td style="text-align: right;">0.00</td> </tr> <tr> <td>Line 8 Computer Charges</td> <td style="text-align: right;">0.00</td> <td style="text-align: right;">0.00</td> </tr> <tr> <td>Line 9 Tuition</td> <td style="text-align: right;">0.00</td> <td style="text-align: right;">2,186.40</td> </tr> <tr> <td>Line 10 Fellowships</td> <td style="text-align: right;">0.00</td> <td style="text-align: right;">0.00</td> </tr> <tr> <td>Line 11 Subcontracts</td> <td style="text-align: right; border-top: 1px solid black;">0.00</td> <td style="text-align: right; border-top: 1px solid black;">0.00</td> </tr> <tr> <td>Line 12 Total Direct Costs</td> <td style="text-align: right;">\$ 0.00</td> <td style="text-align: right;">\$ 151,373.78</td> </tr> <tr> <td></td> <td style="text-align: right;">Withholding 10.00</td> <td></td> </tr> <tr> <td>Line 13 Overhead @ 16%</td> <td style="text-align: right; border-top: 1px solid black;">0.00</td> <td style="text-align: right; border-top: 1px solid black;">35,111.22</td> </tr> <tr> <td>Line 14 Total Costs</td> <td style="text-align: right; border-top: 1px solid black; border-bottom: 3px double black;">\$ 10.00</td> <td style="text-align: right; border-top: 1px solid black; border-bottom: 3px double black;">\$ 186,485.00</td> </tr> </tbody> </table> <div style="margin-top: 20px;"> <p>*Overhead rates of:</p> <p>64% 03-15-88 to 06-30-89</p> <p>16% 07-01-89 to 08-31-91</p> </div>									Amount for Current Period Billed	Cumulative Amt From Inception	<u>Major Cost Elements:</u>			Line 1 Salaries & Wages	\$ 0.00	\$ 112,565.75	Line 2 Fringe Benefits	0.00	27,671.42	Line 3 Materials & Services	0.00	5,096.09	Line 4 Travel	0.00	3,297.86	Line 5 University Services	0.00	556.26	Line 6 Sub Total	\$ 0.00	\$ 149,187.38	Line 7 Equipment	0.00	0.00	Line 8 Computer Charges	0.00	0.00	Line 9 Tuition	0.00	2,186.40	Line 10 Fellowships	0.00	0.00	Line 11 Subcontracts	0.00	0.00	Line 12 Total Direct Costs	\$ 0.00	\$ 151,373.78		Withholding 10.00		Line 13 Overhead @ 16%	0.00	35,111.22	Line 14 Total Costs	\$ 10.00	\$ 186,485.00
	Amount for Current Period Billed	Cumulative Amt From Inception																																																								
<u>Major Cost Elements:</u>																																																										
Line 1 Salaries & Wages	\$ 0.00	\$ 112,565.75																																																								
Line 2 Fringe Benefits	0.00	27,671.42																																																								
Line 3 Materials & Services	0.00	5,096.09																																																								
Line 4 Travel	0.00	3,297.86																																																								
Line 5 University Services	0.00	556.26																																																								
Line 6 Sub Total	\$ 0.00	\$ 149,187.38																																																								
Line 7 Equipment	0.00	0.00																																																								
Line 8 Computer Charges	0.00	0.00																																																								
Line 9 Tuition	0.00	2,186.40																																																								
Line 10 Fellowships	0.00	0.00																																																								
Line 11 Subcontracts	0.00	0.00																																																								
Line 12 Total Direct Costs	\$ 0.00	\$ 151,373.78																																																								
	Withholding 10.00																																																									
Line 13 Overhead @ 16%	0.00	35,111.22																																																								
Line 14 Total Costs	\$ 10.00	\$ 186,485.00																																																								